EPA
United States
Environmental Protection
Agency

Developing Life Cycle Models for Managing Plastics – Understanding Material Flows, Processes, and Potential Consequences

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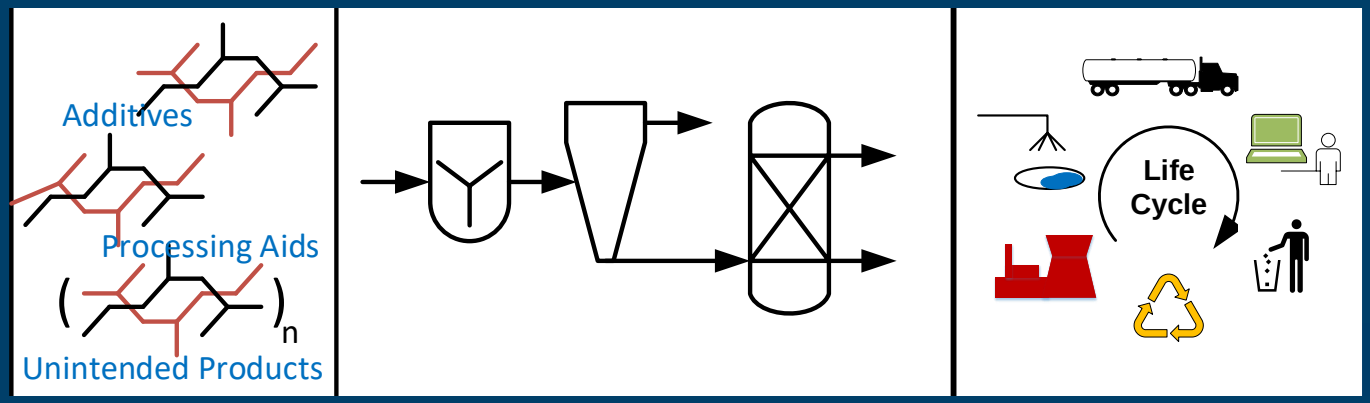

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Disclaimer

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Improving Life-Cycle Models and Increasing Their Usability (Example for Plastics)

- What are the material flows of plastics? This work provides one example.

Generation = Landfill + Recycle + Compost + Energy Recovery

+ Mismanaged Waste (i.e., leakage)

- What are the process profiles for recycling plastics? Material Recovery Facilities (MRF) and reclaimers are modeled to describe resource use and environmental releases.

- The results feed into the USEEIO model and the Waste Measurement Program for Office of Resource Conservation and Recovery (ORCR).

Some Effects of Plastic Pollution

- Marine Litter is estimated to cost the world $264 billion annually.
- Ohio's Lake Erie beaches have 2.8 million visitor days, $88 million in recreational value, $217 million in tourist spending, and 3,700 jobs. More pollution could cut these activities.
- Effects on Human Health and the Environment

U.S. Federal Strategy for Addressing the Global Issue of Marine Litter (2020)

Generation of Plastics

8,300 Mt of plastic produced, 6,300 Mt of plastic waste, since 1950s.[1]
→ Plastic demand in 1950s, about 2 Mt/year,[1] in 2019, 368 Mt/year.[2]
→ Plastic demand expected to quadruple by 2050.[3]

Recycling Opportunities

Metric[4]	Total	Plastics
Jobs	757,325	75,000
Wages	$36.6 billion	$3.2 billion
Tax Revenue	$6.8 billion	$0.3 billion

Mt = Million metric (Mega) tons

1 – Geyer et al., 2017. https://doi.org/10.1126/sciadv.1700782; 2 – Plastics Europe, 2020. Plastics – The Facts; 3 – Ellen MacArthur Foundation, 2017. The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action

4 – 2016 Recycling Economic Information Report Estimates of Contributions of Recycling to U.S. Economic Activity/Quantity and Value Contribution, EPA530-R-17-002

New Law, Save Our Seas 2.0 Act, Shows Importance of Plastics and Associated Pollution

Some EPA responsibilities under SOS 2.0:

Section 133: Study on U.S. Plastic Pollution Data
Section 301: Strategy for Improving Post-Consumer Materials Management and Water Management
Section 303: Study on Repurposing Plastic Waste Infrastructure
Section 305: Report on Eliminating Barriers to Recycling
Section 306: Report on Economic Incentives to Spur New End-Use Markets
Section 307: Report on Minimizing the Creation of New Plastic Waste
Section 302: Grants, $65 million annually for waste management and reduction

Some text of SOS 2.0:

The term ‘‘circular economy’’ means an economy that uses a systems-focused approach and involves industrial processes and economic activities that—

(A) are restorative or regenerative by design;
(B) enable resources used in such processes and activities to maintain their highest values for as long as possible; and
(C) aim for the elimination of waste through the superior design of materials, products, and systems (including business models).

National Recycling Strategy (DRAFT, 2020)

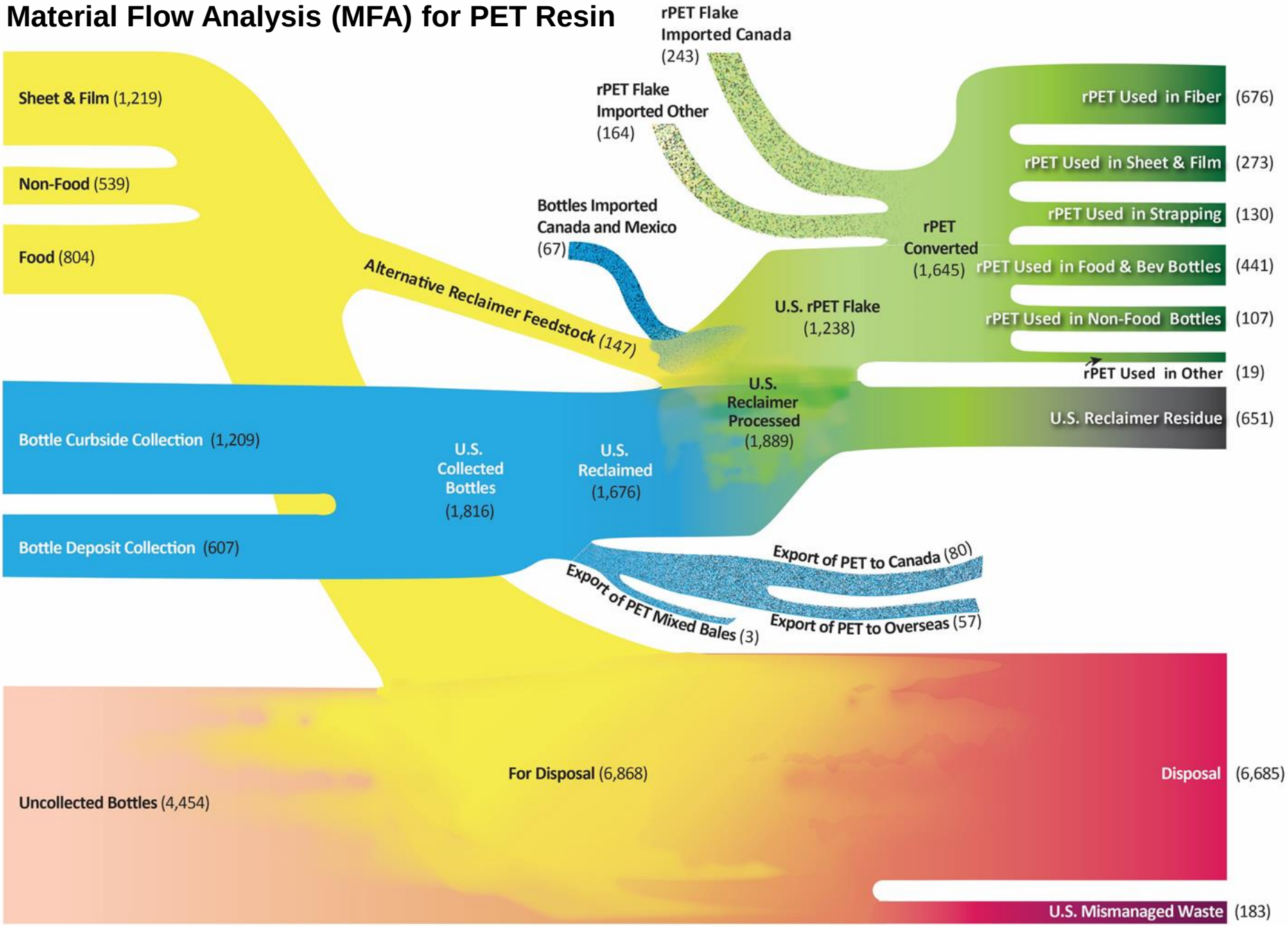
EPA's strategy has three objectives to strengthen the U.S. recycling system:

1. Reduce Contamination
2. Increase Processing Efficiency
3. Improve Markets

→ Approach for Plastics:

a. Understand system flows and barriers to increased recycling
b. Profile processes and impacts
c. Polyethylene terephthalate (PET) as first plastic / system to study

Material Flow Analysis (MFA) for PET Resin



Adapted from NAPCOR (2019) *Postconsumer PET Recycling Activity in 2018*. Flows of PET resin in MMlb.

Material Recovery Facility (MRF) Separation Rates

% of Incoming Streams Leaving in Each Output Material

Incoming Stream	Process and Output Materials				
	Pre-sort for Bulk Plastics	Pre-Sort for Rejects	Disc Screen 1	Fiber Rejects Bunker	Disc Screen 2
	Bulk Plastics	Rejects	OCC	Fiber Rejects	Mixed Paper
Newspaper (ONP)	0.03%	3.64%	0.13%	0.69%	94.91%
Bagged Newspaper	0.17%	37.36%	0.00%	22.96%	36.39%
Corrugated Cardboard (OCC)	0.06%	3.42%	43.88%	1.01%	50.56%

ONP = old newspapers
OCC = old corrugated containers

Augmented H. Damgacioglu et al. (2020) *Waste Management*, 102, 804–814; Separation Rate Table

PET-Item MRF-Sorted Output Material

Example Items are 1. Bottles with Caps and Labels, 2. Clamshells with Labels

PET Bale output material is
95.8% PET items.
6.1% of PET items are dirt and water residue.
11.7% of PET items are other materials (HDPE, adhesive).

Therefore, the PET Bale is 78.0% PET, so even for this “great” example of recycling plastics, there are barriers to increased recycling.

	PET Optical Sorter
	PET Bale
PET Bottles	89.0%
Natural HDPE Bottles	0.1%
Colored HDPE Bottles	0.3%
Non-Bottle PET	6.8%

Part of Separation Rate Table for PET Bale Output Material

Reclaiming PET – Removing Unwanted Impurities

Actual and Theoretical Performance

Reclaiming involves

1. Opening Bales
2. Sorting Out Unwanted Materials
3. Grinding the Plastics
4. Washing
5. Density Separation
6. Air Drying
7. Air Sifting

Yield is 97% of PET during reclaiming, resulting in 75.7% PET from original PET Bale.

This compares to 65.5% of PET flake reclaimed from collected bottles according to the Material Flow Analysis (MFA) diagram. Theoretical model appears to present an opportunity for better performance.

Process Profiles: Resource Use and Emissions per Metric Ton of MRF and Reclaimer Feed

Resource Use or Release	Units	MRF	Reclaimers
Electricity	kWh / ton of feed	13.7	251.7
Diesel Use	L / ton of feed	0.75	0.75
Baling Wire	kg / ton of feed	1.559	--
Natural Gas	scm / ton of feed	0.516	0.051
Sodium Hydroxide	ton / ton of feed	--	0.0047
Water Use	ton / ton of feed	--	0.188
Wastewater	L / ton of feed	0.631	188
Diesel Storage Emissions	kg / ton of feed	2.3×10^{-6}	2.5×10^{-6}
Greenhouse Gases	kg CO2 equiv. / ton of feed	8.58	103.7
Additional Emissions	Detailed in Supporting Info of Journal Article*		

R.L. Smith et al. (2021). *ACS Sustainable Chemistry & Engineering*, submitted*.

Paper vs Plastic

Generalizations about Differences in Recycling Systems for Two Materials

	Paper	Plastic
Who	Businesses	Households
Where	Commercial	Single-Family Homes
When	On Own Schedule	Community Schedule
How	Sorted to Reclaim	Single Stream to MRF
Why	Policy	Good Thing to Do
What	Cardboard, Office Paper (i.e., all are the same material, wood fiber)	#1 PET #2 HDPE #3 PVC #4 LDPE #5 PP #6 PS #7 Other

Plastics in Flux

Changing Systems, Many Unknowns, and Research Opportunities

EPA's ORCR, USEEIO, and Measurement Needs

China National Sword

Basel Convention

COVID-19

Pressure from Ellen MacArthur Foundation

Brand Commitments

State and Local Actions

Chemical Recycling

Plastics #3-7 MFA and Process Profiles

Textiles

Microplastics

Additives and Processing Aids